DATA ACQUISITION TECHNIQUES FOR EXPLOSIVE HIGH CURRENT GENERATORS

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ABSTRACT

The Hydrodynamic and X-Ray Physics Group (P-22) at Los Alamos National Laboratory has developed hardware, software, and procedures to work with explosively driven high current generators to obtain time resolved data. Data recording in this physically and electrically harsh environment requires special equipment, techniques, and processes. There are three distinct areas of consideration to record this class of data. First is the explosive shot pad area, second is bunker area, and third is the data handling and documentation considerations. It is well within the capability of P-22 to provide 100 to 200 data recording channels and to provide 50 to 100 fiber optic data paths to the recording area. The equipment has high frequency bandwidths from 20 MHz to 500 MHz.

This work has been conducted in various sites in the United States and Russia. The work in Russia presents a particular challenge in the areas of planning for the change in AC power voltage and frequency, different coaxial and connector systems, making sure all components and spare equipment are included in the equipment shipped before the experiment.

To avoid ground loops and EMI noise problems fiber optic techniques are used to deliver the data from the shot pad to the recording area in the bunker. Data from electrical B-dot, V-dot, Rogowski, X-ray diodes, Faraday Rotation current measurements, are all part of the diagnostic probes that are routinely recorded by our data acquisition systems.

Shielded 50 Ohms coaxial cables deliver the electrical probe signals to an area close to the device, generally about 50 feet, behind a blast shield. Behind the blast shield will be several EMI shielded boxes containing fiber optic transmitters and proper attenuation for the probe signals. There will be different EMI shielded boxes for electrical probes, depending on different electrical potentials on the device. These fiber optic transmitters are battery powered and are allowed to float electrically.

The bunker area contains the fiber optic receivers, waveform digitizers, triggering equipment and data acquisition computers. From the shot pad area optical fibers provide the signal path into the bunker and the fiber optic receivers. Where necessary the bunker ground loops are broken with fiber optic trigger hardware and large-scale un-interuptable power supplies (UPS). These units have storage batteries to provide clean AC power to operate the data recording equipment during the experiment.

The handling of the data and documentation of the data is considered part of the data recording effort. Calibrations of time and amplitude before the event provide post event corrections for the data. The data is stored on the computer and is available for data analysis programs. In addition, documentation of the experimental setup is provided for pre-event review and post-event analysis.

TEXT

Pre-shot Considerations

One of the first steps of any physics experiment is to determine probes, data signal levels, data transmission techniques, type of data recording equipment, and size of data acquisition system required. This is based on the mission of the experiment and pre-shot calculations. The initial and continuing discussions about the required data acquisition package to support the physics mission is an ongoing process right up to shot time. This involves the definition of the probes for the physics of interest, physical considerations of probe placement, access for installation and methods for the signals to be ported to the data acquisition (DAQ) system. These considerations must be compatible with the facility where the experiment will be preformed. After the array of diagnostics and probes are defined, the process of designing a DAQ system to meet the dynamics of probe type, bandwidth, time history, signal

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amplitude, proper signal amplitude coverage, redundancy, and number data channels will determine the actual reality of producing the DAQ package. Considerations of electrical noise, shielding, and ground loops are a major factor in the design and implimination of these diagnostics systems. When 0.5 volt signal levels, or less, are recorded in an electrical environments of 10's of megamps and 100's of kilovolts special designs are required and special attention to every detail allows these DAQ designs to deliver quality data. In addition the explosive environment that drives these physics experiments requires physically hardened enclosures or explosive mitigation techniques to be part of the DAQ design.

Data Acquisition System Capability

The group, X-Ray and Hydrodynamics (P-22), at Los Alamos National Laboratory, has designed and developed techniques to make high bandwidth and high-resolution measurements to meet the criteria demanded by explosive high current generators. Below is a list of probes or diagnostic techniques that P-22 supports. This list can be expanded as new ideas and process are required.

Diagnostic Type	Data Transmission Method
B-dot Probes	Coaxial cable to EMI box and fiber optic data link
V-dot Probes	Coaxial cable to EMI box and fiber optic data link
Voltage Gap Probes (current joints)	Coaxial cable to EMI box and fiber optic data link
Rogowski Probes	Coaxial cable to EMI box and fiber optic data link
Faraday Rotation of global current	Fiber optic cable to data recording area
Optical Pins	Fiber optic cable to data recording area
Silicon X-Ray Detectors	Coaxial cable to EMI box and fiber optic data link
Neutron Detectors	Coaxial cable to EMI box and fiber optic data link

P-22 also has an inventory of equipment to support up to DAQ systems of several hundred channels of data. Below is a general list of the types, specifications, and quantities of this inventory:

Fiber Optic Links (for electrical probes in EMI and physically hardened enclosures)	
20 Hz to 75 MHz	50 Channels
1.5 kHz to 500 MHz	100 Channels
Faraday Rotation Current Measuring Systems	5 Systems or more
Optical Receiver for Optical Pins, 100 MHz or greater	50 Channels or more
Waveform Digitizers	
10 ns, 8 bit, 128K memory	50 Channels or more
4 ns, 8 bit, 128K memory	20 Channels or more
0.5 ns, 8 bit, 16K memory	75 Channels or more
Time Interval Meters, 50 ps resolution	75 Channels or more
Un-intuptable Power Supplies	5 KVA with 30-minute capacity

These experiments are expensive and require a high confidence to return quality data. From a DAQ point of view accurate documentation and system dry run (amplitude and time calibration) enhance the process of quality data return.

Shot Pad Issues

One shot pad issue concerns the interface of the high current generator device and the proper installation of the array of probes. Many of these probes must be installed during the assembly of the device. The teams of physicists, engineers and technicians must work together to assure the probes are installed with known geometry and assurance of the probe operating properly. The physical location and calibration constants for the probes are included in the documentation package for post-shot analysis. On joint physics experiments such as the Mago and High Energy Liner experiments both Russian and USA probe sets must be coordinated well before the shot to avoid

conflicts and to have the proper machining, installation, probe labeling, and output connections. The use of telephone calls, FAX, and face to face interactions are used to provide this interaction.

Knowledge of the shot pad and bunker layouts are required to pre-build the coaxial and fiber optic cable for signal transmission. The actual time of access on the shot pad is in the area of two weeks, with the actual current generator on the shot pad for 1 to 2 days. During the two weeks the shot pad is prepared for mitigation of the blast for data acquisition devices to be recovered after the shot. This mitigation uses angled steel plate blast shield, concrete blocks, heavy steel pipes, sandbags, and dirt. Signal and control cables are then installed. During this same time the data recording equipment in the bunker or recording area is set up and dry runs of the system are made.

A general technique used by Los Alamos is to electrically isolate all shot pad signals from the data recording area by using extensive fiber optics. Los Alamos techniques depend heavily on the use of batteries to power equipment on the shot pad to avoid ground loops and radiated noise pick up. These batteries range from simple 9-volt transistor batteries to operate the lasers for the Faraday rotation measurement to 40 Amp-Hour 12-volt batteries to operate the fiber optic transmitters. Electrical insulation installed between the EMI boxes that house the fiber optic transmitters. The fiber optic transmitters are grouped by common electrical potential on the current generator to avoid ground loops.

The fiber optic transmitters are housed in heavy gauge steel EMI shielded enclosure with up to 16 transmitter in each enclosure. Electrical signals pass through bulkhead connectors and are the signals are scaled using attenunators to match the 0.5 linear voltage range of the 50ohm input impedance of the transmitters. Special protection circuits allow over voltage of the inputs to +/- 1 kilovolt without damage to the transmitter. The fiber optic links are amplitude modulated and have better than a 40 dB signal to noise ratio.

After the device arrives on the shot pad the team works on final diagnostic installation and hook up. Activities include:

- Verification of proper cable and fiber hook up
- Physical location of diagnostics
- Attention to error signal pickup
- Ground loop isolation
- Installation of attenunators for diagnostic channels
- Battery connection
- Photographing and writing down of diagnostic installation

Recording/Bunker Area Issues

Recording/Bunkers area issues must consider the following items for successful operations. Many of these items must be determined well before the shot and many others must be determined during the two week of experimental set up time.

	Before Shot	While at Bunker
AC Electrical Power and Cooling		
120 VAC 60 Hz or 220 VAC 50 Hz	X	X
Amount of AC power required	X	
Noise on the AC power lines at shot time	X	
Adequate equipment and personnel cooling	X	X
Electrical Noise Sources		
High Voltage Firing Units	X	X
Ground Loops	X	
Radiated signals	X	
Amount of Floor Space for DAQ setup		
Low traffic area		X
Good communications with operating personnel		X
Avoid locations close to electrical noise sources		X
Access to the Shot Pad		
Cable and Fiber paths to shot pad	X	
Location of ports to shot pad		X

	Before Shot	While at Bunker
Triggering Sources and Accuracy		
Signal source location		X
Signal voltages, polarity, and time duration		X
Ground loops	X	X
Electrical noise isolation	X	X
System timing diagram	X	X
System accuracy	X	X
Safety Concerns		
Know the Standard Operating Procedures		X
Know the responsible personnel		X
Interface with the Firing Site Operator and Operations		
Interface with dry run and trigger tests		X
Know of the required tests the facility		X
Know the schedule(s) (daily, weekly, pre-shot, post shot)		X
Write a checklist for shot day activities		X
Documentation		
One-line diagrams	X	X
Spreadsheets of system details	X	X
Daily logbook of activities	X	X
Photographs		X

The list above outlines many of the areas that need to be addressed in the data recording area. By the time one enters the shot pad and recording area, the experiment is well defined, diagnostics are settled, data recording is settled, initial documents have be drafted, AC power issues are established, and the team is ready to go to work.

The set up of the data recording system, checkout, calibration, and final preparations for shot time are the main pre-shot bunker activities. The daily flow of work involves:

- Equipment Setup and Checkout
- Document Experimental set up
- Verify the computer programs and files
  - Digitizer setup Parameters
  - Arming of Digitizers
  - Digitizer readout and data archive
- Dry run the experimental set up inside the bunker
- Verify all timing and amplitude calibrations
- Establish and verify proper trigger sequence with operations personnel
- Move shot pad signal cables and fibers from bunker to shot pad
- Dry run the experimental setup in the bunker and on the shot pad
- Verify all timing and amplitude calibration from the dry run tests
- Replace or repair equipment as necessary
- Prepare checklist
  - Early Pre-shot
  - Late Pre-shot
  - Zero-time
  - Post-Shot
- Final diagnostic hook up and shot attenuator installation
- Charge or install new batteries

Documentation and Analysis Issues

The documentation begins in the conceptual discussions of the experiment. P-22 uses one-line diagrams, spreadsheets, photographs, computer data files, and daily logbooks to document the experiment. DAQ setup is provided to the principle investigator for pre-shot review and verification of proper experimental setup.

Documentation is an ongoing task that allows the probe signal information collected from the DAQ system to be properly analyzed.

The pre-shot dry runs provide individual data channel calibration of timing with resolution from 1 to 10 ns, and amplitude in the area of +/- 2%. These calibration factors are then applied to the data after the shot.

Analysis of the data is a cooperative effort between the data recording and physics personnel. The documentation packages provide the information to change raw signals into scaled physical units. Computer data analysis programs are used to manipulate the data. Some programs are in house written applications and others are commercial software packages. Operations on the data include time corrections, time shifts, overlay of waveforms, vertical offset shifts, scale factor corrections, waveform integration, and zoom in of areas of interest enable the physicists to extract meaningful information from the experiment.